

Neural Language Priming

Marten van Schijndel
Department of Linguistics, Cornell University
February 01 2022

What are effective language processing representations?



We can explore the space using priming

What is priming?

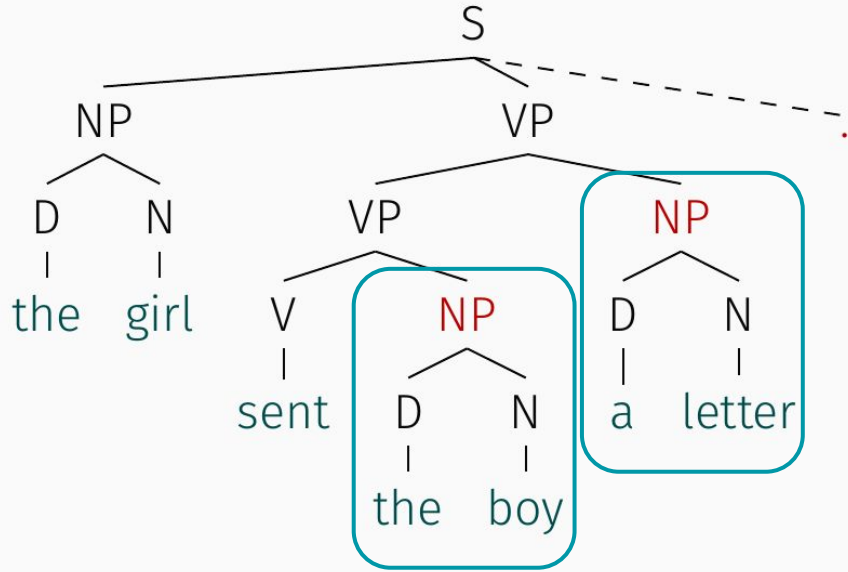
... cassowary ...

Cassowaries ...

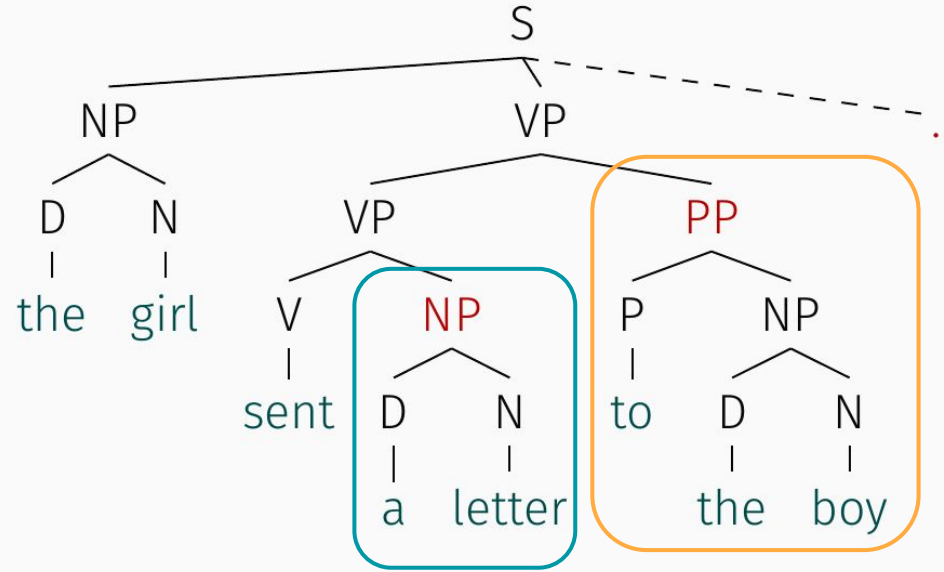
... Just like a cassowary!

... cassowary ...

What is structural priming?



Double object



Prepositional object

What is structural priming?

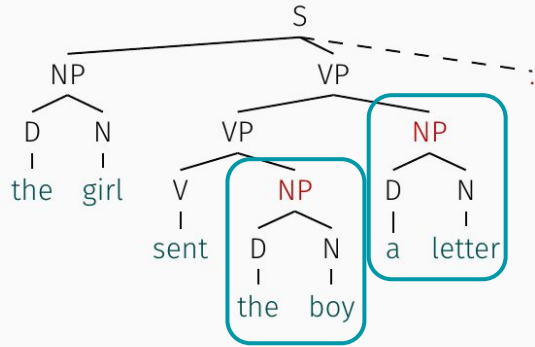
A rockstar sold some cocaine to the undercover agent.

...

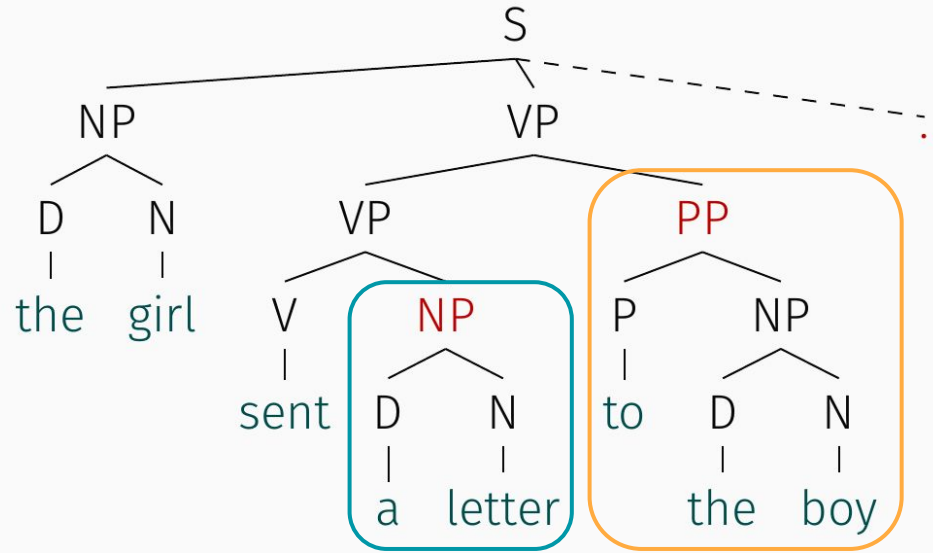
The girl sent a letter to the boy.

(Bock, 1986)

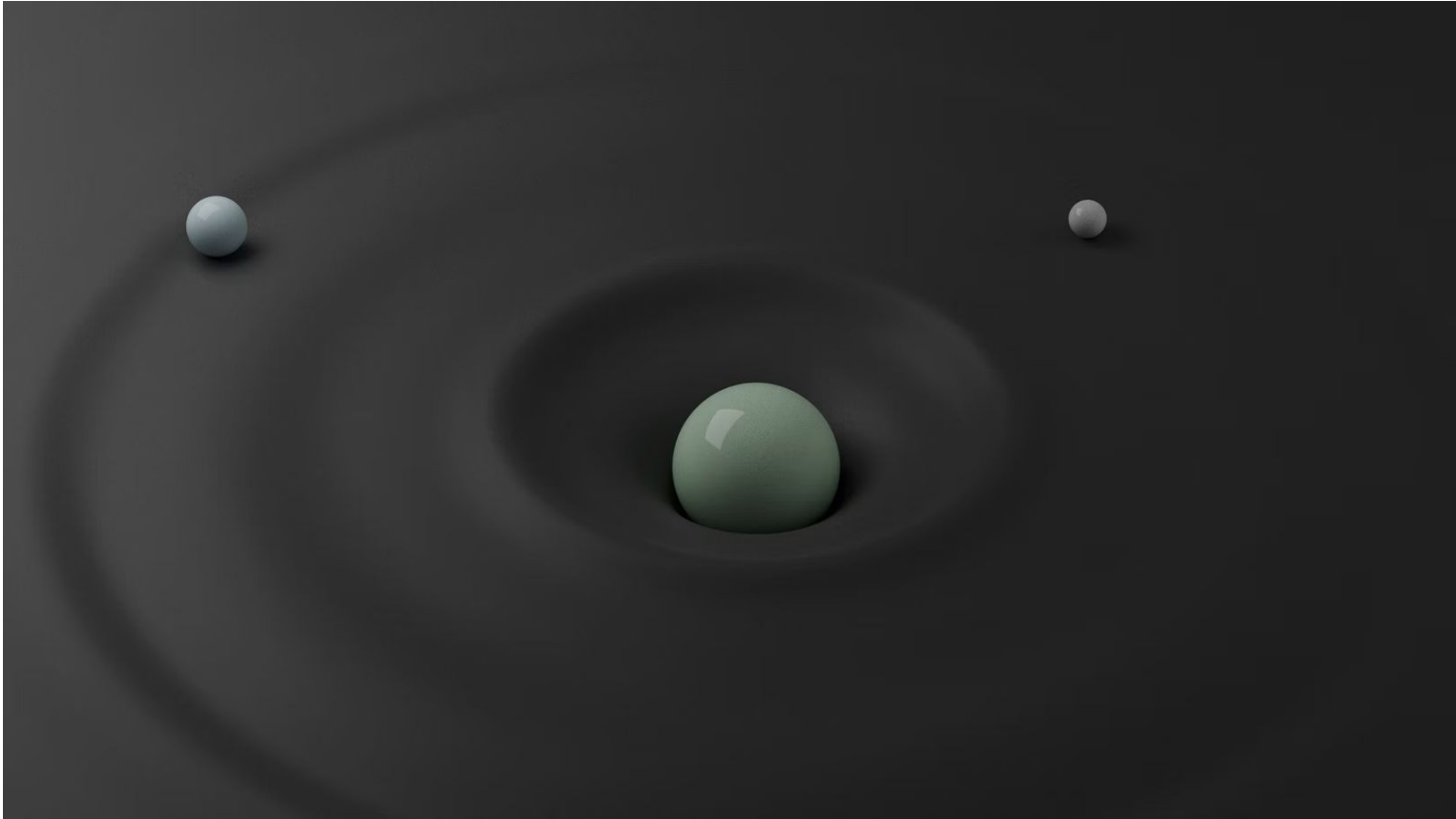
What is structural priming?



Double object



Prepositional object



Why expect this to work with NNs?

NNs require large amounts of data to train

Small amounts of training data should skew distributions according to sensitivity without wholly retraining them

Neural language models can be primed



Tal Linzen

A Neural Model of Adaptation in Reading

Marten van Schijndel
Department of Linguistics
Cornell University
mv443@cornell.edu

Tal Linzen
Department of Linguistics
New York University
linzen@nyu.edu

Proceedings of EMNLP 2018

Adaptation priming algorithm

- 1) Test on a sentence
- 2) Update weights by fine-tuning on that sentence
- 3) Repeat on remaining sentences

Conclusions

- Better linguistic accuracy
- Better psycholinguistic accuracy

The man named
the child as his
sole heir.

Wiki
(1000)

DO
(100)

The boy threw
the dog a ball.

Adapt
Set

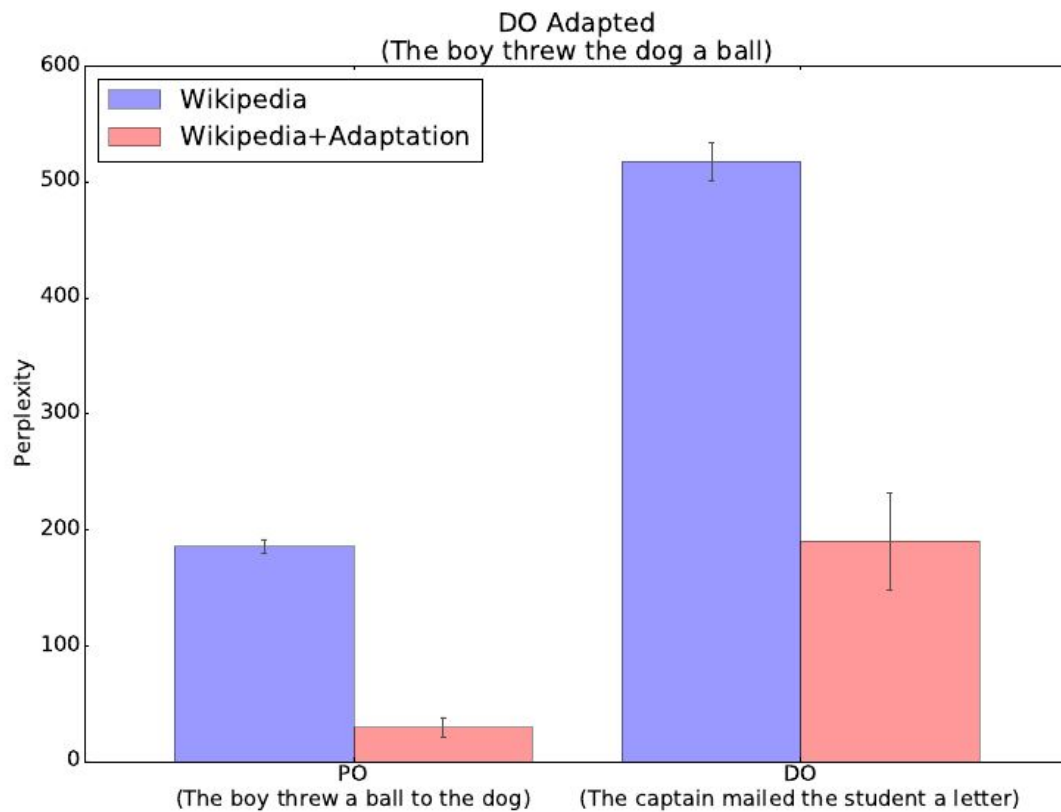
Language
Model

The boy
threw a ball to
the dog.

PO
(100)

DO
(100)

The captain mailed
the student a letter.



Cumulative priming reveals underlying structure



Grusha Prasad



Tal Linzen

Using Priming to Uncover the Organization of Syntactic Representations in Neural Language Models

Grusha Prasad
Johns Hopkins University
grusha.prasad@jhu.edu

Marten van Schijndel
Cornell University
mv443@cornell.edu

Tal Linzen
New York University
linzen@nyu.edu

Proceedings of CoNLL 2019

Cumulative priming reveals underlying structure

Abstract structure	Example
Unreduced Object RC	The conspiracy that the employee welcomed divided the beautiful country.
Reduced Object RC	The conspiracy the employee welcomed divided the beautiful country.
Unreduced Passive RC	The conspiracy that was welcomed by the employee divided the beautiful country.
Reduced Passive RC	The conspiracy welcomed by the employee divided the beautiful country.
Active Subject RC	The employee that welcomed the conspiracy quickly searched the buildings.
PS/ORC-matched Coordination	The conspiracy welcomed the employee and divided the beautiful country.
ASRC-matched Coordination	The employee welcomed the conspiracy and quickly searched the buildings.

Cumulative priming reveals underlying structure

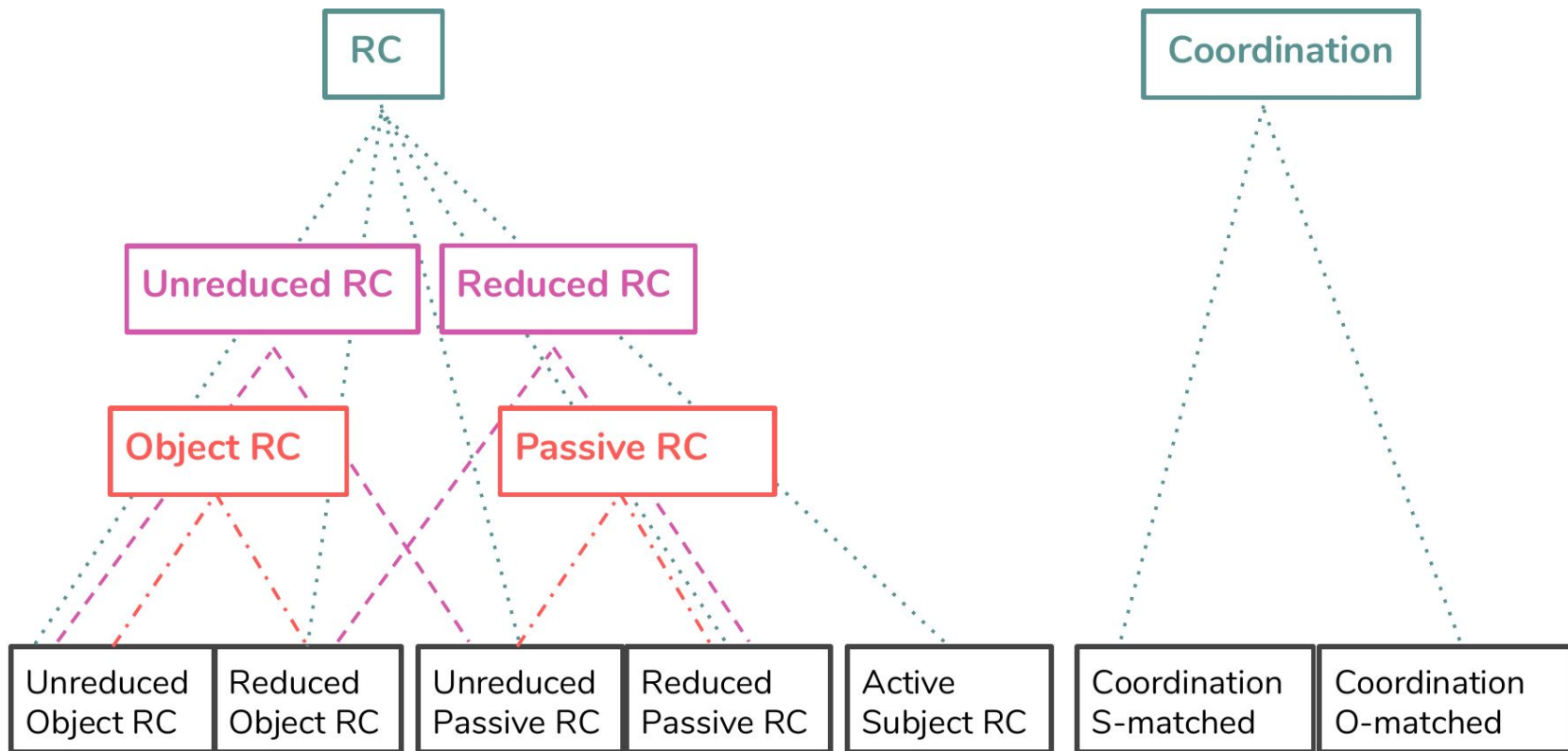
Abstract structure	Example
Unreduced Object RC	The conspiracy that the employee welcomed divided the beautiful country.
Reduced Object RC	The conspiracy the employee welcomed divided the beautiful country.
Unreduced Passive RC	The conspiracy that was welcomed by the employee divided the beautiful country.
Reduced Passive RC	The conspiracy welcomed by the employee divided the beautiful country.
Active Subject RC	The employee that welcomed the conspiracy quickly searched the buildings.
PS/ORC-matched Coordination	The conspiracy welcomed the employee and divided the beautiful country.
ASRC-matched Coordination	The employee welcomed the conspiracy and quickly searched the buildings.

Cumulative priming reveals underlying structure

Abstract structure	Example
Unreduced Object RC	The conspiracy that the employee welcomed divided the beautiful country.
Reduced Object RC	The conspiracy the employee welcomed divided the beautiful country.
Unreduced Passive RC	The conspiracy that was welcomed by the employee divided the beautiful country.
Reduced Passive RC	The conspiracy welcomed by the employee divided the beautiful country.
Active Subject RC	The employee that welcomed the conspiracy quickly searched the buildings.
PS/ORC-matched Coordination	The conspiracy welcomed the employee and divided the beautiful country.
ASRC-matched Coordination	The employee welcomed the conspiracy and quickly searched the buildings.

Cumulative priming reveals underlying structure

Abstract structure	Example
Unreduced Object RC	The conspiracy that the employee welcomed divided the beautiful country.
Reduced Object RC	The conspiracy the employee welcomed divided the beautiful country.
Unreduced Passive RC	The conspiracy that was welcomed by the employee divided the beautiful country.
Reduced Passive RC	The conspiracy welcomed by the employee divided the beautiful country.
Active Subject RC	The employee that welcomed the conspiracy quickly searched the buildings.
PS/ORC-matched Coordination	The conspiracy welcomed the employee and divided the beautiful country.
ASRC-matched Coordination	The employee welcomed the conspiracy and quickly searched the buildings.



Priming reveals abstraction depth



Deb Bhattacharya

Filler-gaps that neural networks fail to generalize

Debasmita Bhattacharya and Marten van Schijndel

Department of Linguistics

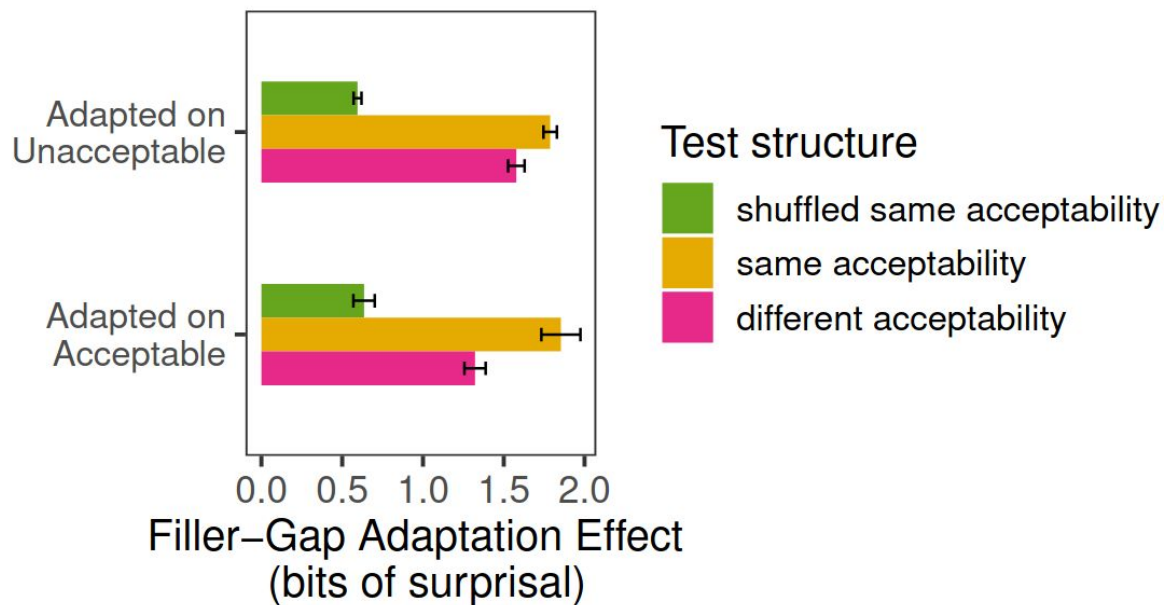
Cornell University

{db758 | mv443}@cornell.edu

Proceedings of CoNLL 2020

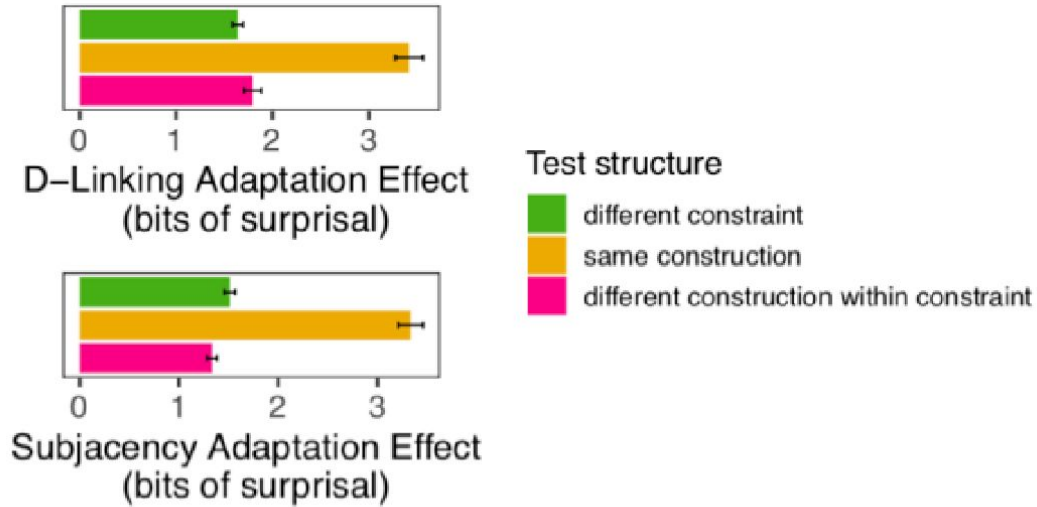
Construction	Examples
Adjunct island Wh- island Subject island	*What did you go home because you needed to do __? *Whom did Susan ask why Sam was waiting for __? *Who is that __ went home likely?
Left branch island Coordinate structure island	*Whose does Susan like __ account? *What did Sam eat __ and broccoli?
Complex NP island	*What did you hear the claim that Fred solved __?
Object extraction Non-bridge verb island	Who is it probable that Bill likes __? *How did she whisper that he had died __?

Networks encode broad FG existence



Construction	Examples	L	S	E	D
Adjunct island	*What did you go home because you needed to do __?	-		-	
Wh- island	*Whom did Susan ask why Sam was waiting for __?		-		(+)
Subject island	*Who is that __ went home likely?	-	-	-	
Left branch island	*Whose does Susan like __ account?		-		(+)
Coordinate structure island	*What did Sam eat __ and broccoli?			+	
Complex NP island	*What did you hear the claim that Fred solved __?		-		
Object extraction	Who is it probable that Bill likes __?	+		+	(+)
Non-bridge verb island	*How did she whisper that he had died __?	?	?		

Networks do not encode abstract FG constraints



Priming reveals constraint-like interactions



Forrest Davis

Uncovering Constraint-Based Behavior in Neural Models via Targeted Fine-Tuning

Forrest Davis and **Marten van Schijndel**

Department of Linguistics

Cornell University

{fd252|mv443}@cornell.edu

Proceedings of ACL 2021

(a) Sally frightened Mary because she was so terrifying.

Who is terrifying?

(a) Sally frightened Mary because she was so terrifying.



(a) Sally frightened Mary because she was so terrifying.



(a) Sally frightened Mary because she was so terrifying.



Who is terrifying?

Sally

(b) Sally feared Mary because she was so terrifying.

Who is terrifying?

(b) Sally feared Mary because she was so terrifying.



Who is terrifying?

Mary

Implicit Causality

- Some verbs are **subject-biased**
 - *frightened, amused, astonished, enraged*

- Others are **object-biased**
 - *feared, admired, loved, hated*

English

Evaluating English BERT for IC behavior

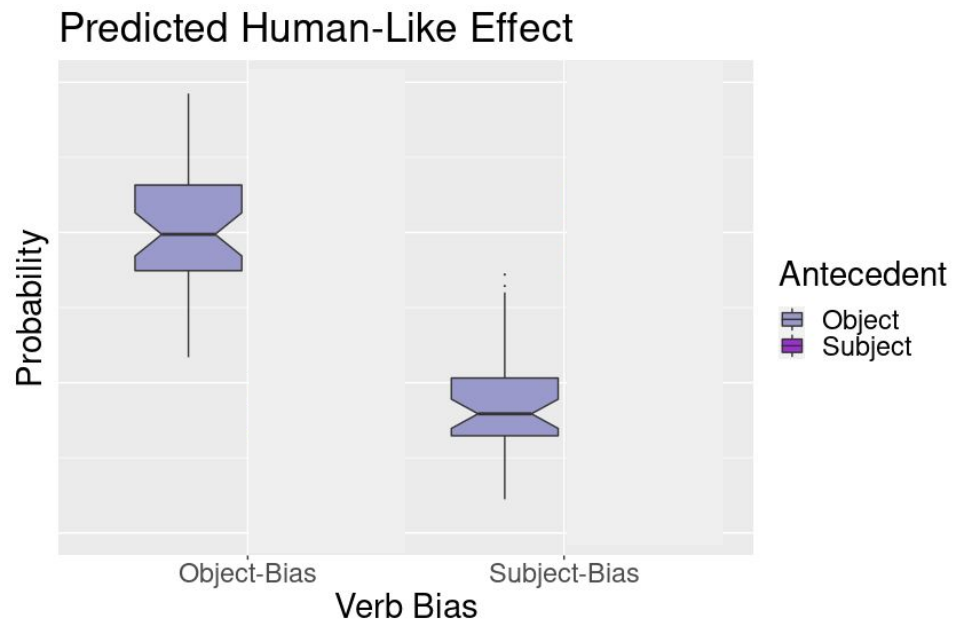
the **man** admired the **woman** because [MASK] was there.

- ~300 IC verbs from Ferstl et al. (2011)
- 14 pairs of M/F nouns (e.g., king-queen)
(balanced for gender and position)
- bert-base-uncased (HuggingFace)
- Expect higher probability for pronouns agreeing with the bias
(admire = object-biased)
 - $P(\text{she}) > P(\text{he})$

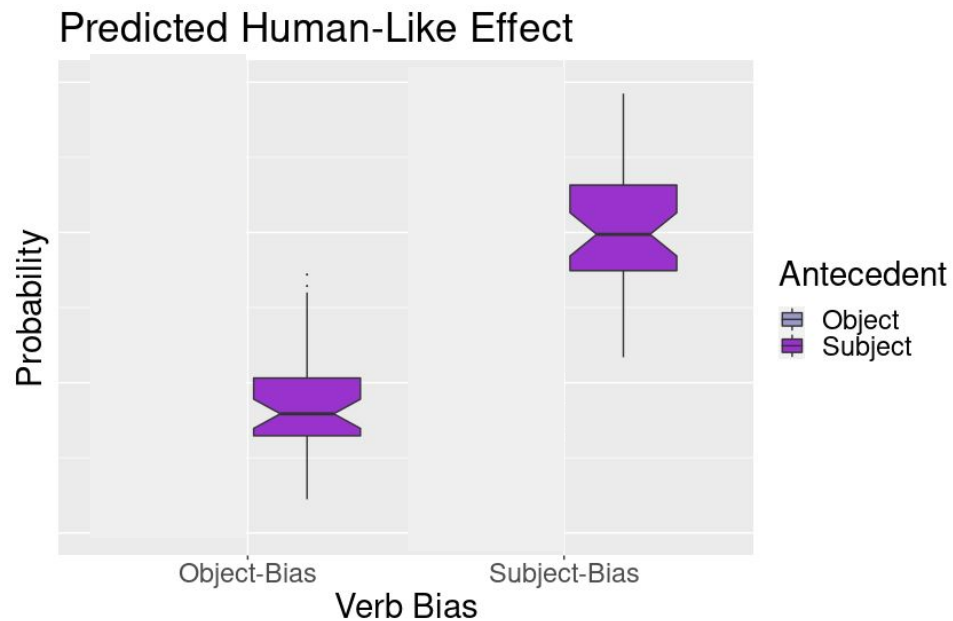
Evaluating English BERT for IC behavior



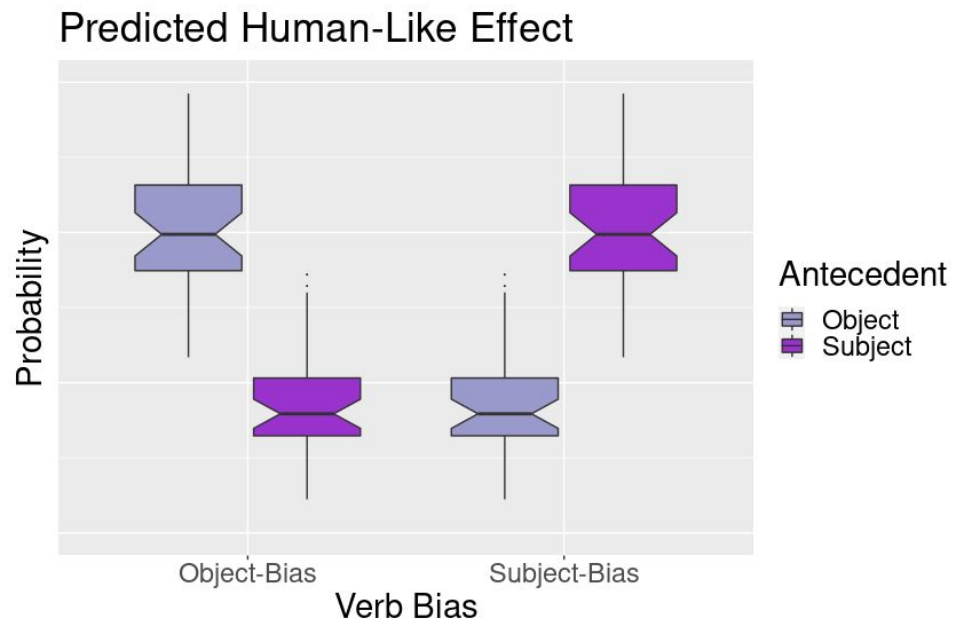
Evaluating English BERT for IC behavior



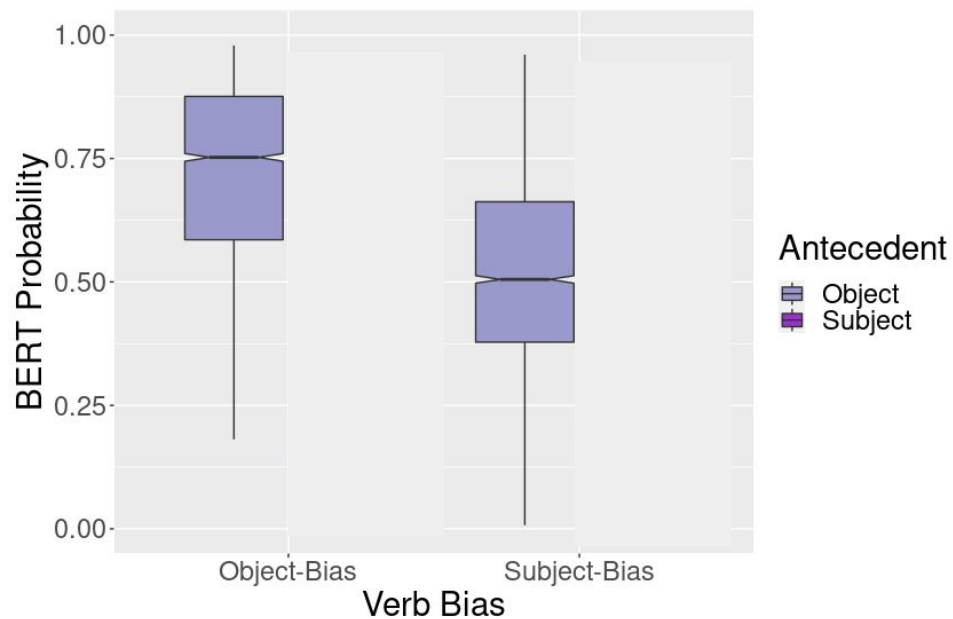
Evaluating English BERT for IC behavior



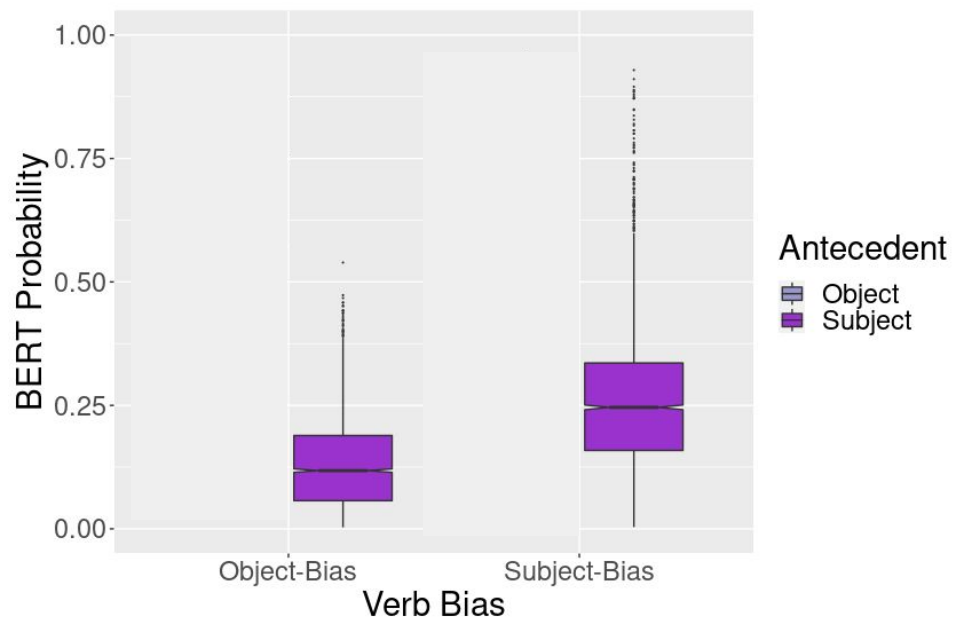
Evaluating English BERT for IC behavior



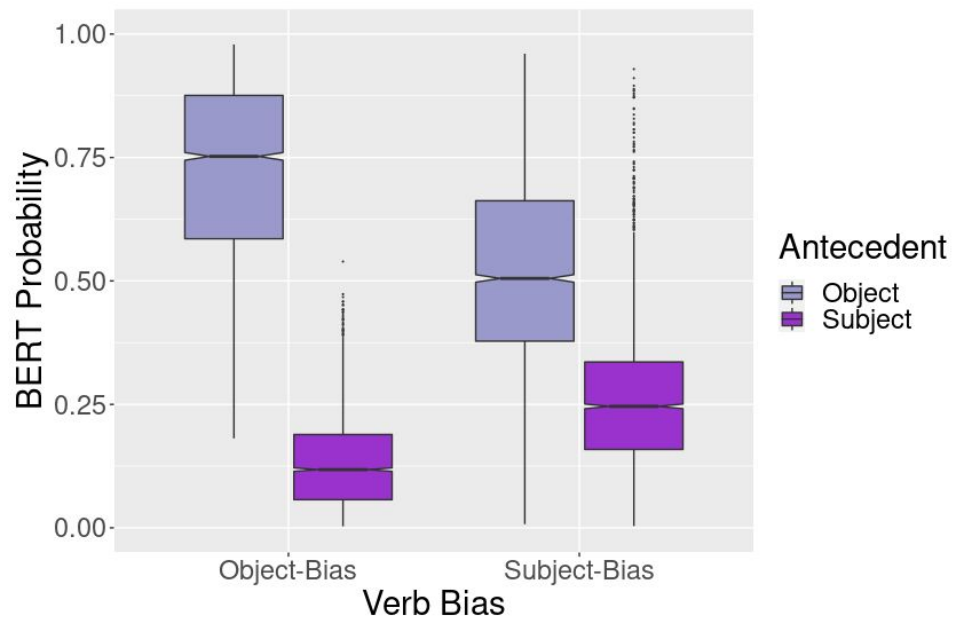
English BERT shows IC behavior



English BERT shows IC behavior



English BERT shows IC behavior



IC is attested cross-linguistically

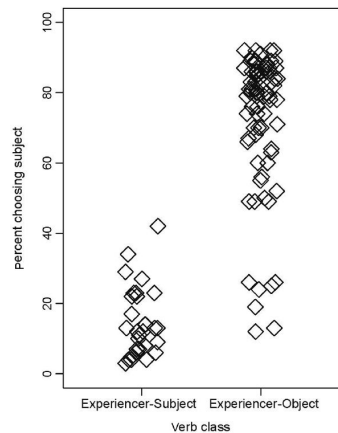


Figure 6. Degree of subject-bias for English emotion verbs reported in Ferstl, Granham, Manouilidou (in press).

English

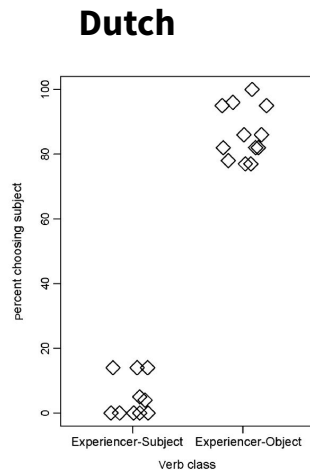


Figure 8. Degree of subject-bias for Dutch emotion verbs reported by Koornneef and van Berkum (2006).

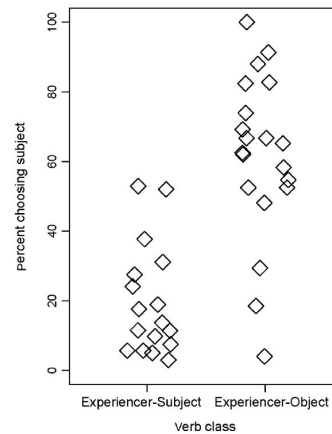


Figure 7. Degree of subject-bias for emotion verbs in Spanish as reported by Goikoetxea et al. (2008).

Spanish

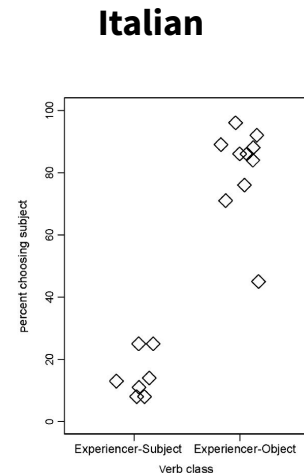


Figure 9. Degree of subject-bias for emotion verbs in Italian as reported by Mannetti and de Grada (1991).

from Hartshorne et al. (2013)

Spanish & Italian

Evaluating Spanish BERT for IC behavior

el **hombre** admiró a la **mujer** porque [MASK] estaba allí.

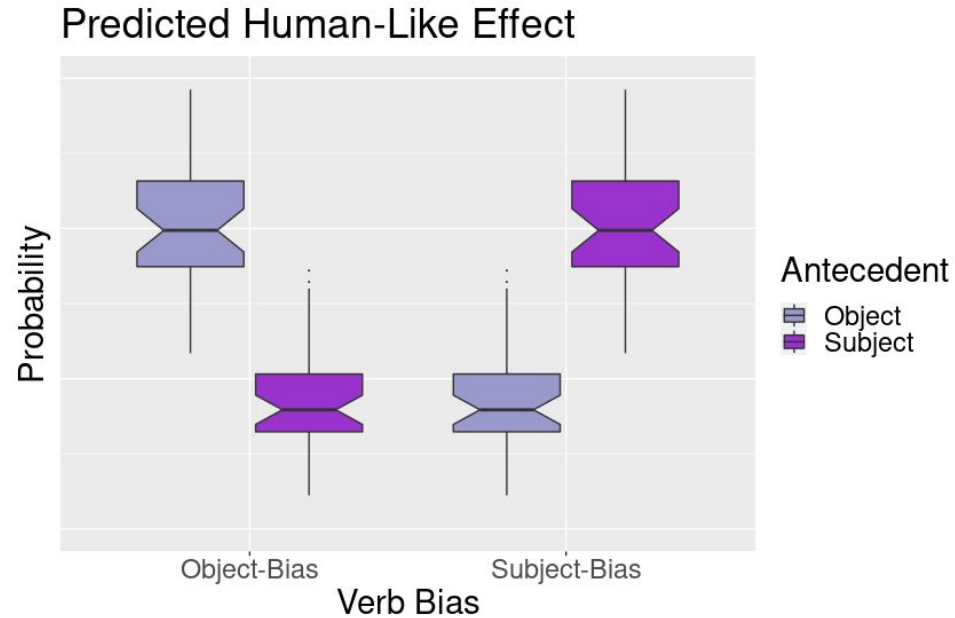
- 100 IC verbs from Goikoetxea et al. (2008)
- 14 pairs of M/F nouns (balanced for gender, position)
- dccuchile/bert-base-spanish-wwm-uncased (aka **BETO**; HuggingFace)
- Expect higher probability for pronouns agreeing with the bias
(admiró = object-biased)
 - $P(\text{ella}) > P(\text{él})$

Evaluating Italian BERT for IC behavior

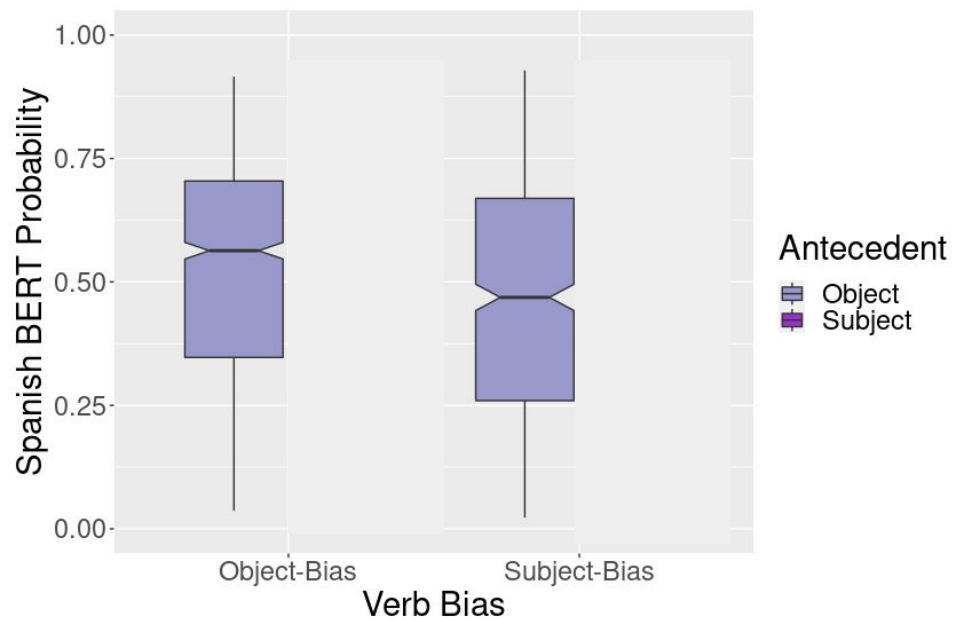
l'uomo lusinga la donna a causa del tipo di persona che [MASK] è.

- 40 IC verbs from Mannetti and de Grada (1991)
- 14 pairs of M/F nouns (balanced for gender, position)
- dbmdz/bert-base-italian-uncased (HuggingFace)
- Expect higher probability for pronouns agreeing with the bias
(lusinga = object-biased)
 - $P(\text{lei}) > P(\text{lui})$

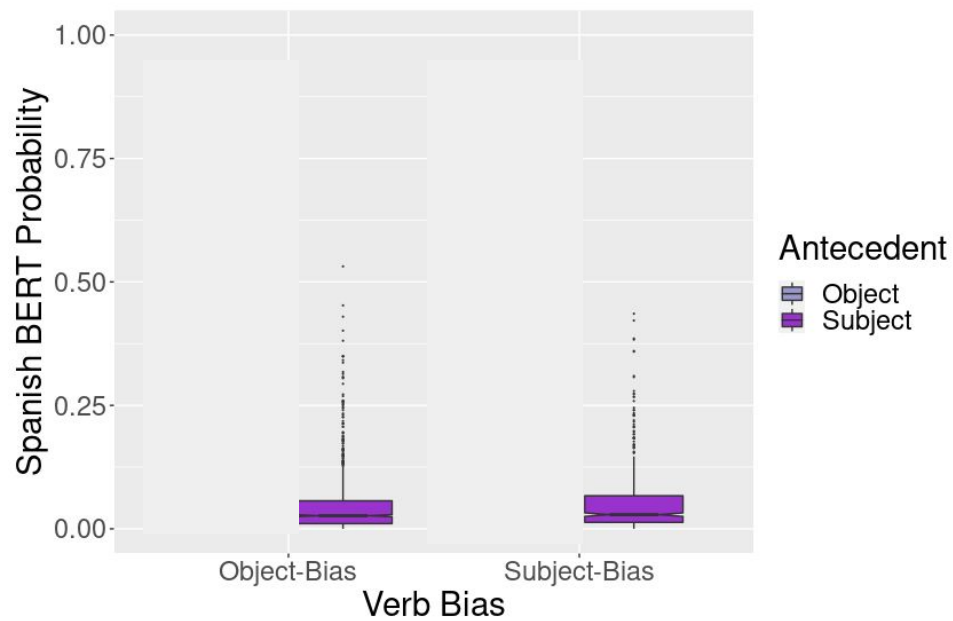
Recall what we want to see



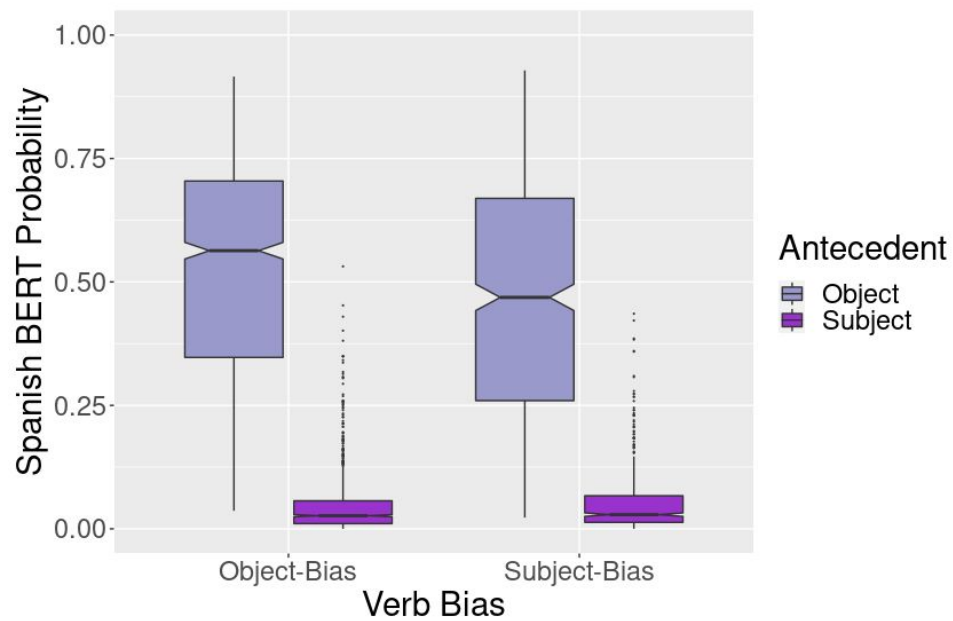
Spanish BERT partial? IC behavior



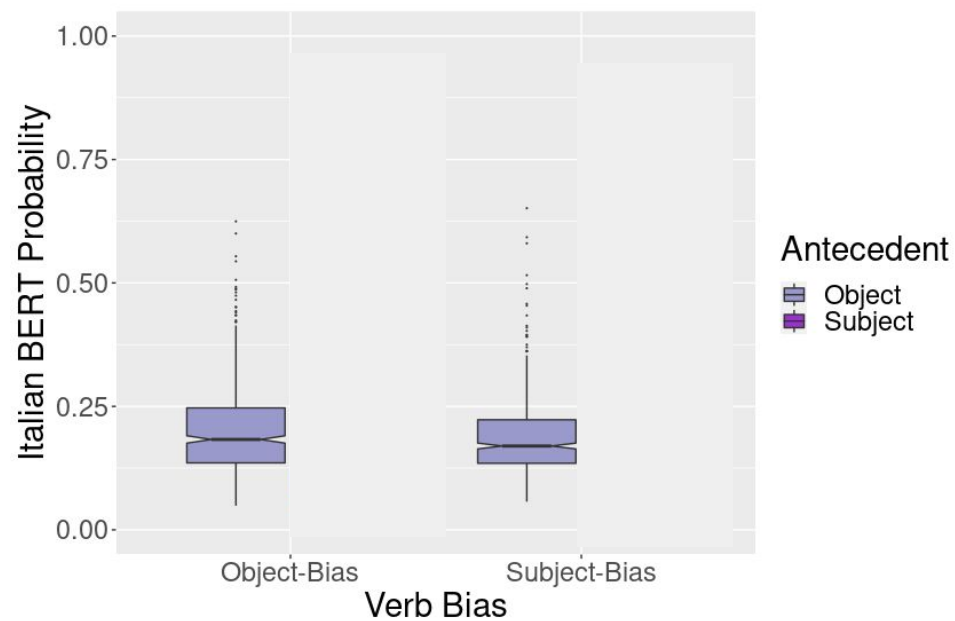
Spanish BERT partial? IC behavior



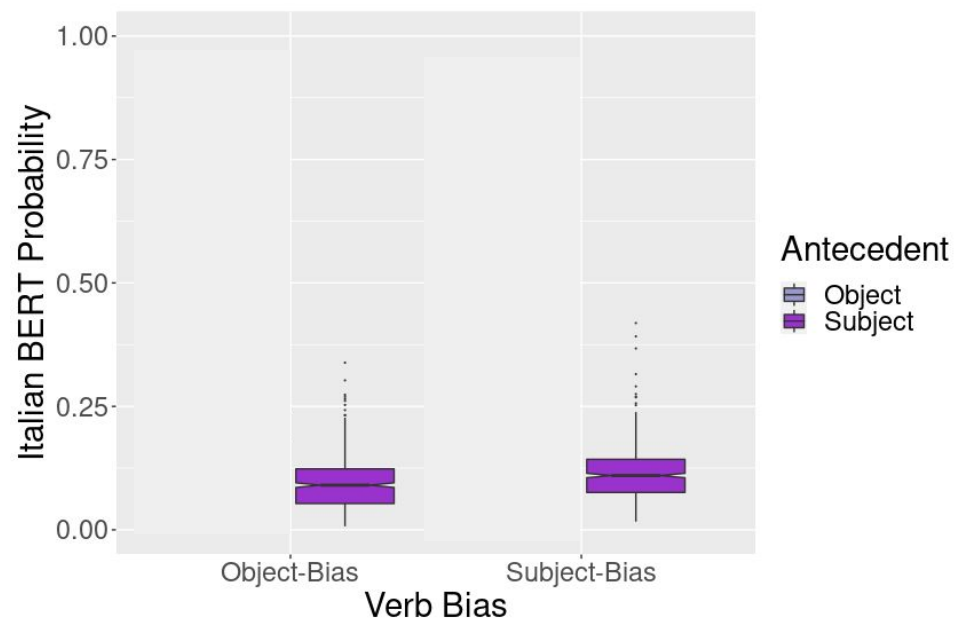
Spanish BERT partial? IC behavior



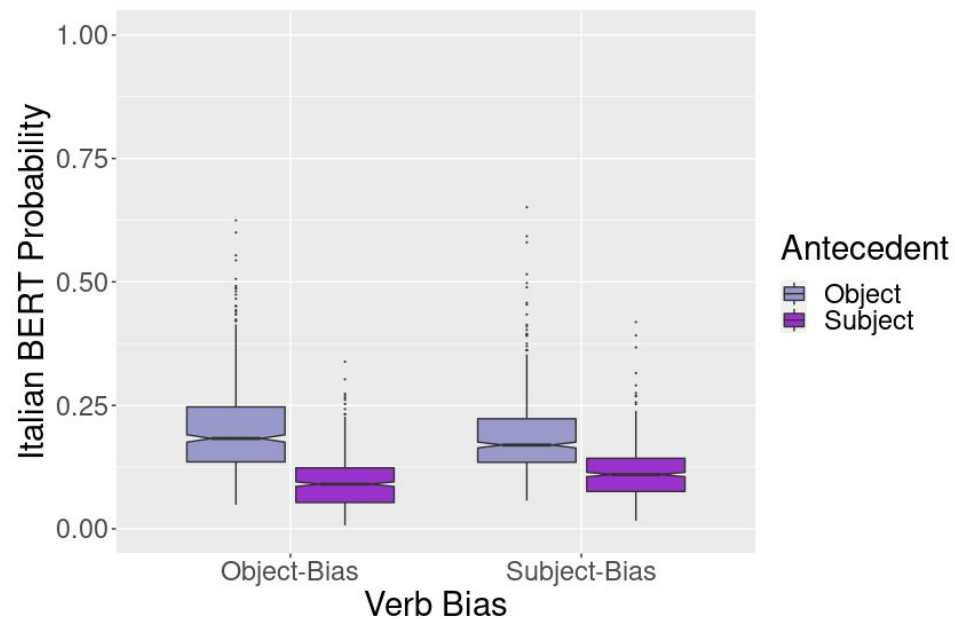
Italian BERT no IC behavior



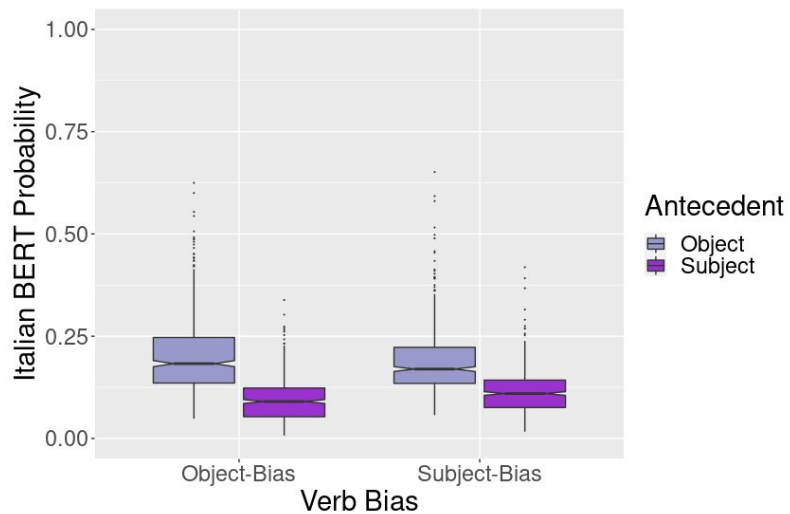
Italian BERT no IC behavior



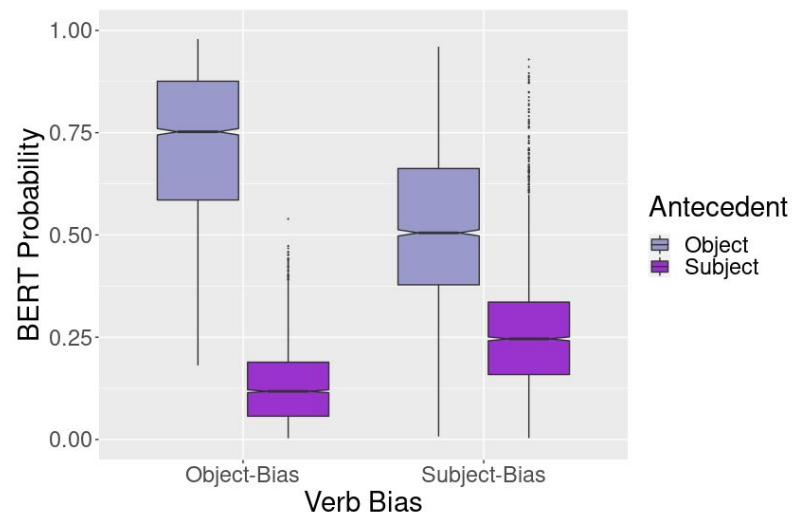
Italian BERT no IC behavior



Italian BERT no IC behavior



Italian

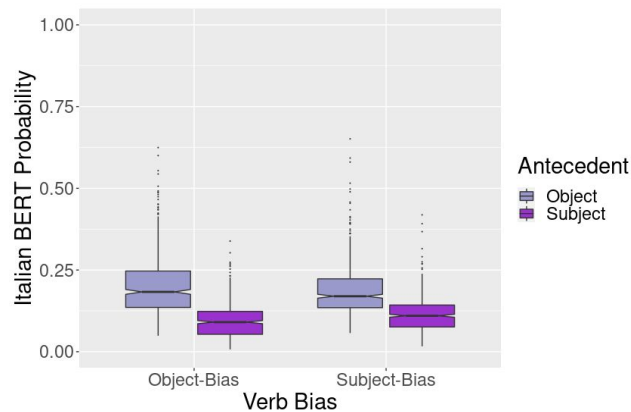


English

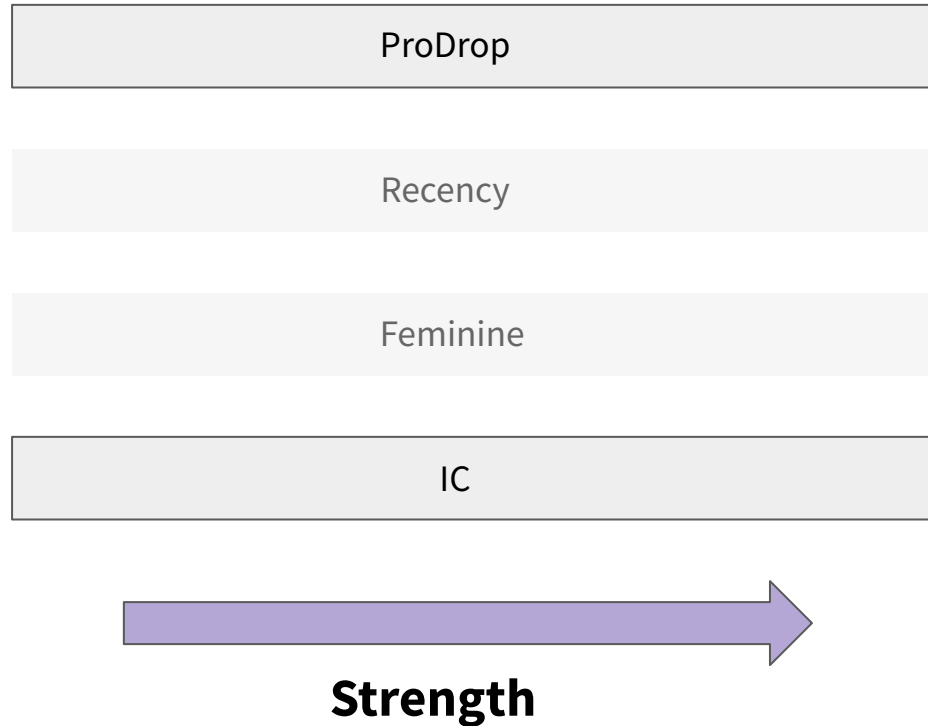
Why aren't we learning IC in Spanish & Italian

- IC is not the only process affecting pronouns
- ProDrop: Overt pronouns in subject position are ungrammatical or dispreferred

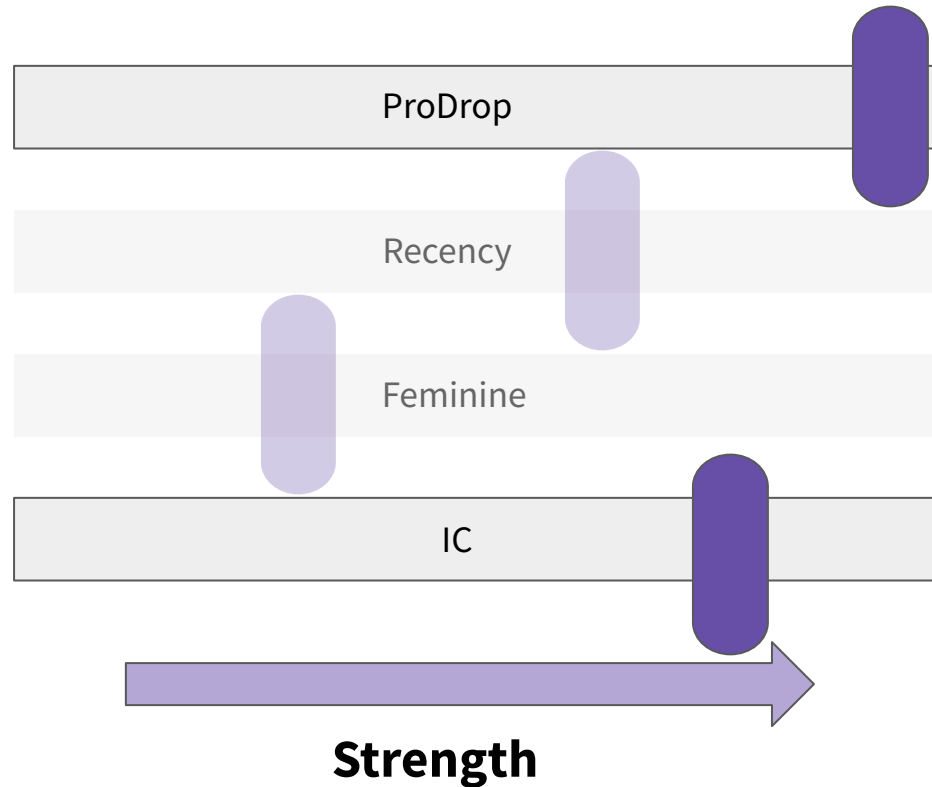
- is happy vs. *he is happy



Processes as Constraints



Processes as Constraints



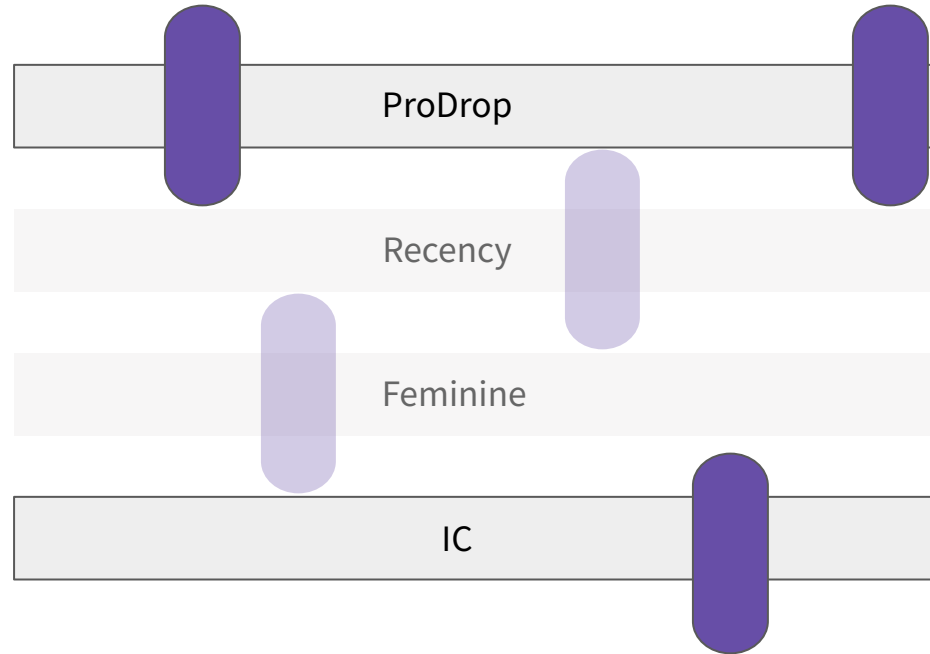
**The man
admired
the woman
because __
was there**

ProDrop Competes with IC bias

ProDrop outranks IC

Can we promote IC by demoting ProDrop?

Processes as Constraints



**The man
admired
the woman
because she
was there**

Demoting ProDrop with Fine-tuning

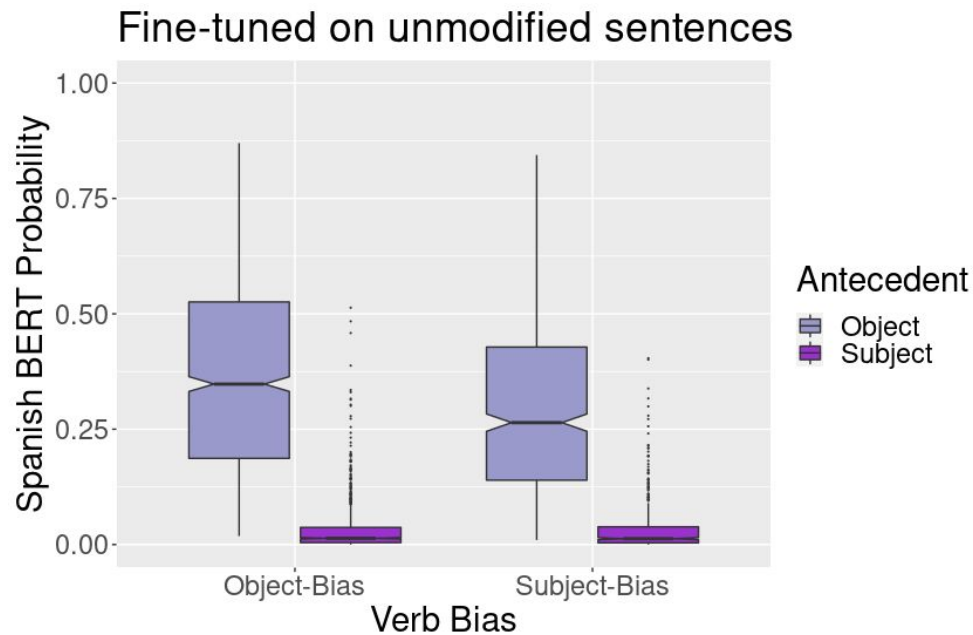
Method: Add pronouns to Spanish/Italian ProDrop sentences

UD datasets (AnCorra Spanish, Italian ISDT and VIT)

- Find finite verbs w/o nsubj relation, filtering out test IC verbs
- Added a pronoun matching the verb's person and number
- Resulted in 4000 Spanish sentences (~3500 he/she)
4600 Italian sentences (~2000 he/she);
0.005% of original training data
- Fine-tuned Spanish and Italian BERT for 3 epochs (lr=5e-5)

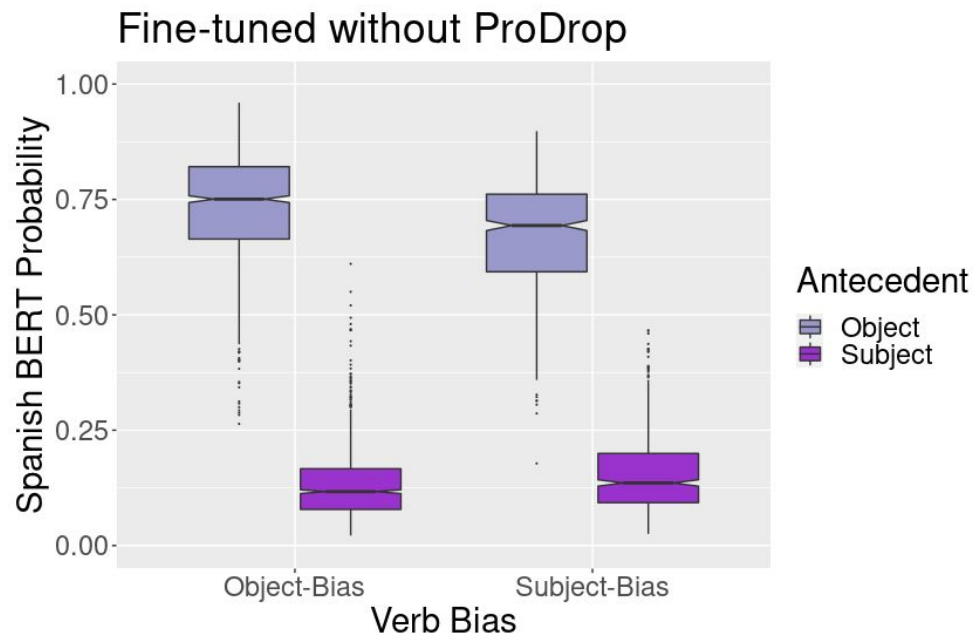
Spanish Baseline

- Unmodified sentences



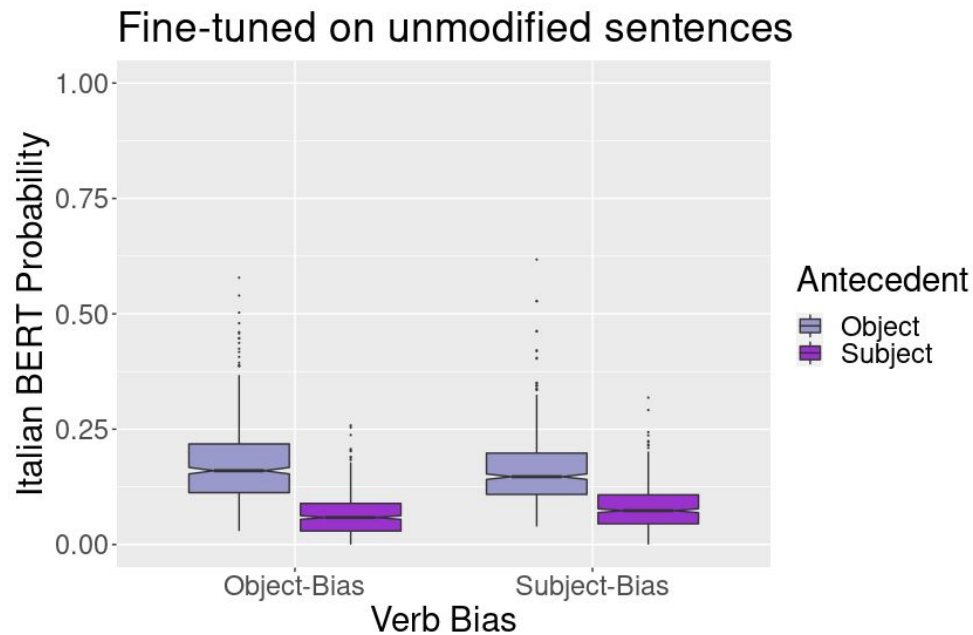
Spanish Fine-tuned

- Sentences without ProDrop



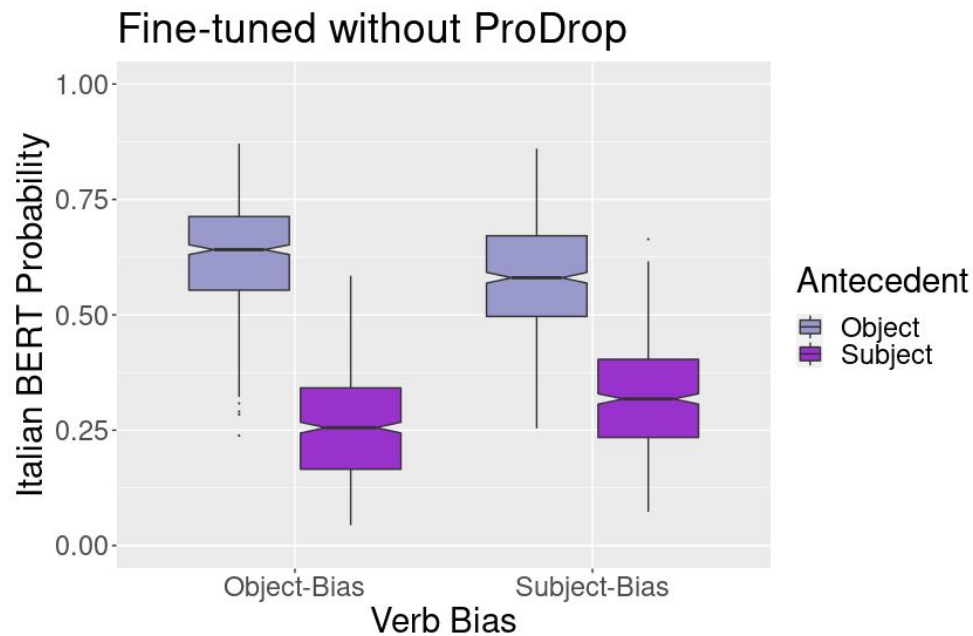
Italian Baseline

- Unmodified sentences



Italian Fine-tuned

- Sentences without ProDrop



Summary

- Standard behavioral probing: IC is only learned by **English** models
- In fact, Spanish and Italian models also learn IC but it conflicts with ProDrop
- **Removing ProDrop** via fine-tuning on a small number of ProDrop violations **revealed IC knowledge**
 - We explicitly train on data for a process we are **not** testing (i.e. we are not training on IC data)

Conclusion

- Adaptation priming is effective for:

Better text
predictions

Better human
predictions

Probing
representations

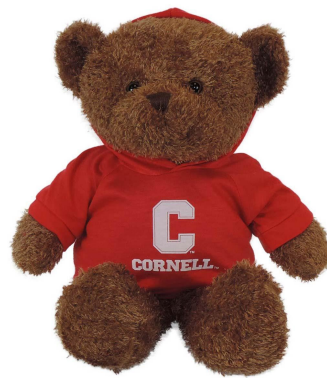
- Priming can probe **feature clusters** and **constraint/feature rankings**
- In addition to **single phenomena** (usually English)
need to study **interactions** (signals compete)

Give it a try!

Thanks!



C.Psyd



Cornell NLP